

Applicant : Jan Antonis
Serial No. : 10/822,476
Page : 7

REMARKS/ARGUMENTS

Applicants acknowledge the Examiner's review of the specification and claims. The amendments and remarks presented herein are fully supported by the application as originally filed. No new matter has been entered.

Status of Claims

Claims 1-15 are pending in the application.

Overview

The present invention concerns a system that is capable of inspecting an object – and in particular taking a three dimensional measurement of the object – from a single image of the object taken by a single camera that is fixed with respect to the object when the image is taken. Because there is a single camera taking a single image from a fixed position, the captured image cannot properly represent the object in three dimensions. In particular, the true or “real world” position of the upper edges of the object will not be correctly represented by the raw captured image data. This is because the raw captured image data can only record the position of the object in two dimensions (i.e. the X-Y plane defined by the work surface) and, in the case of upper edges of the object (which are necessarily offset above the work surface, because of the thickness of the object) the offset above the work surface causes the X-Y position of the upper edge as recorded in the captured image data to be different from the real world X-Y position. This is sometimes referred to as a “parallax error”.

Conventionally, this problem would be overcome by taking multiple images of the object and combining the data from the multiple images to produce a real world representation of the object. Multiple images are obtained either by moving the camera and object relative to one another, by using multiple cameras in different positions relative to the object, and/or by using lasers or other structured light patterns to perform a scanning function. However, these options are considered to be expensive.

Applicant : Jan Antonis
Serial No. : 10/822,476
Page : 8

The present invention avoids the expense of multiple cameras, moving parts, scanning lasers or the like, by using a single camera in a fixed position with respect to the object. In order to overcome the parallax problem outlined above, the system of the invention processes the captured image data, after it has been projected onto the object plane, in the manner described in Claim 1 and, in preferred embodiments, as recited in the dependent claims.

In contrast, US 6,571,196 (Kosuge) discloses an inspection system in which the object (2) to be inspected is movable with respect to the camera (1) by means of an XY stage (6) and an XY driver (see Figure 2 and column 4, lines 14 to 18). The particular problem being addressed by Kosuge is to provide a technique that allows contours of the object to be determined in two dimensions in cases where the contour is rounded or the captured image is obscure (see Abstract, column 1, lines 55 to 64 and column 3, lines 33 to 53). Kosuge is not concerned with, and does not disclose, how captured two dimensional image data could be converted into three dimensional "real world" data. More specifically, Kosuge describes a technology which allows sub-pixel detection of edge position in an obscure 2D image. The 2D image edge locations are then compared to the 2D image edge locations of a reference object.

With regard to US 5,974,169 (Bachelder), Bachelder describes a technology to determine the position, size, centre of mass, boundary and orientation of 2D shapes in a 2D image. Bachelder does not detail how real world 3D object measurements are calculated from the 2D image shapes. More specifically, Bachelder is concerned with recognising characteristics, e.g. an edge of an object, in a 2D image to facilitate the inspection and/or placement of the object (see column 1, lines 7 to 21 and column 3, lines 22 to 30). In particular, Bachelder's invention is concerned with creating, "bounding boxes" to help identify the object's boundaries in the 2D image (see abstract). Bachelder is not concerned with generating, from the captured image data, three dimensional data representing the object, although Bachelder does compare the image data with a reference model in order to help identify the image characteristics.

Applicant : Jan Antonis
Serial No. : 10/822,476
Page : 9

With regard to US 6,604,795 (Buckley), Buckley describes a technology to measure the 3D shape of an object by moving the object in front of the camera and by shining a structured light, specifically laser light, onto the object. While Buckley's system does measure the real world 3D object shape, it requires the use of lasers or other structured light patterns and multiple images. Furthermore, it requires that the object be moved by scanning the object underneath the sensors (see Figure 1 and columns 5, lines 57 to column 6, line 5), or uses multiple cameras for inspecting all sides of the object in a single pass (see Figure 5). In either case, Buckley uses triangulation as the means for constructing a model of the object (column 5, lines 65 to column 6 line 5) since multiple images are provided.

In summary, none of Kosuge, Bachelder or Buckley are attempting the same task as is addressed by the present invention, namely to produce three dimensional object data from a single captured image. Kosuge, Bachelder and Buckley each have movable cameras, movable objects, multiple cameras or scanning lasers and so are able to take multiple images of the object. This means that they do not need to employ the techniques recited in the claims of the present application since they are able to construct three dimensional object data from multiple images. It is considered that the teachings of Kosuge, Bachelder or Buckley, either individually or in combination, would therefore lead a skilled person away from the subject matter of Claims 1 to 13 towards the conventional solutions described in paragraphs [0004] to [0007] of the present Patent application.

Claim Rejections 35 USC s 103

Applicant agrees with the Examiner that Kosuge does not disclose the following features of Claim 1:

- A. The processing apparatus is arranged to project each image edge data component onto the object plane to produce a respective object edge data component in the object plane.
- B. The processing apparatus is arranged to determine whether each object edge data component relates to an edge of the object that lies on the work surface or to an edge of the object that is offset above the work surface.

Applicant : Jan Antonis
Serial No. : 10/822,476
Page : 10

- C. The apparatus is arranged to receive the image data components from the camera and to generate, using said image data components, three dimensional data representing the object.
- D. Wherein in order to generate said three dimensional data the apparatus is arranged to identify a plurality of said image data components that represent the position of the respective edge component of the object in an image plane.

However, applicant submits that Claim 1 is also novel over Kosuge by virtue of the following feature:

- E. The apparatus is arranged to, upon determining that an object edge at a component relates to an edge of the object that is offset above the work surface, adjust the value of the object edge data component by an amount depending on the ratio of the size of the offset in a direction generally perpendicular with the work surface to the perpendicular distance of the camera's focal point from the object plane.

With regard to Feature E, the Examiner contends that this feature is the same as adjusting the field of view of the camera. Applicant respectfully disagrees. Adjusting the field of view of a camera is something that is done prior to taking an image. In the passage identified by the Examiner (Colum 8, lines 62 to 64), Kosuge discloses that the object to be inspected is moved by the XY stage (6) until it comes into the field of view of the optical microscope (1). This is done to correctly position the object with respect to the camera and therefore takes place prior to the image being captured. Once image data has been captured, subsequently adjusting the field of view of the camera will have no effect on the previously captured image data. In contrast, Feature E of Claim 1 relates to processing the captured image data after it has been captured in order to compensate for parallax error as described above. This is achieved by adjusting the value of the object edge data component in the manner defined in Feature E. Because this adjustment takes place on image data that has already been captured (or more specifically on object edge data that has been created from the image data), it cannot be affected by adjusting the camera's field of view, nor could this adjustment be replicated by adjusting the camera's field of view. Applicant agrees that adjusting the field of view of the camera prior to capturing an image will have an effect on the actual data that is captured but

Applicant : Jan Antonis
Serial No. : 10/822,476
Page : 11

this is a separate issue to that addressed by Feature E of Claim 1. To put this another way, in order to perform the invention of Claim 1, the operation of Feature E would still be required to address the parallax error problem irrespective of any adjustments made to the field of view of the camera prior to capturing the image. One way to avoid needing Feature E would be to change the field of view, i.e. move the object or camera, in order to capture multiple images and then to combine the multiple images using, for example, the triangulation technique taught by Buckley. As explained above, this is a conventional technique that the invention is avoiding by using only a single image.

Further, since Kosuge does not disclose Feature A of Claim 1, i.e. it does not disclose that the image edge data components are projected onto the object plane to produce respective object edged data component, then it cannot disclose Feature E of Claim 1 since Feature E requires an adjustment of the object edged data component. Also, since Kosuge does not disclose Feature B of Claim 1, then it cannot disclose Feature E either since these two features are mutually dependent.

More generally, the adjustment defined by Feature E of Claim 1 above is specifically intended to compensate for parallax error in the captured image data. This is only a concern when trying to generate three dimensional "real world" object data from the captured image data. This compensation cannot be effected by adjusting the camera's field of view since, for any three dimensional object, the parallax error will be present in the captured image data irrespective of any adjustments of the camera's field of view. Since Kosuge is not concerned with generating three dimensional real world data from captured two dimensional image data, he does not identify or address the parallax problem and so does not disclose or suggest Feature E above.

The Examiner argues that Bachelder discloses Features A and B of Claim 1 as set out above. The Applicant respectfully disagrees. With regard to Features A and B, Bachelder is not concerned with generating, from the captured two dimensional image data, three dimensional "real world" data representing the object. All of the labelling operations and bounding box related operations disclosed by Bachelder are performed on the two dimensional captured image data in order to allow Bachelder to determine the position, size, centre of mass,

Applicant : Jan Antonis
Serial No. : 10/822,476
Page : 12

boundary and orientation of two dimensional shapes from the two dimensional captured image data (see for example the abstract of Bachelder). The purpose of Bachelder is to provide an analysis of the two dimensional captured image data that allow it to be compared to expected characteristics of the real world object for inspection purposes (see for example column 10 lines 40 to 45). More particularly, the passages referred to by the Examiner, namely column 2, lines 31 to 34 and column 2, lines 26 to 29, relating to bounding boxes and labelling is performed on the two dimensional captured image data in order to help to identify two dimensional shapes in the image data (see for example Claim 1 in which it is clear that the bounding box activities are performed on the 2D image). Bachelder is not concerned with projecting the image edge data components onto the object plane to produce a respective object edge data component (since it is not concerned with converting the 2D image data into corresponding 3D real world data) and so is not concerned with determining whether an object edge data component (which is a 3D real world data component) relates to an edge of the object that lies on the work surface or offset above the work surface. It is noted that Bachelder does make a decision on whether or not a point in the 2D image data may correspond to a top edge of the corresponding real world object, but it does this by first determining if the point lies in a particular bounding box and then making a comparison with a model of the real world object (column 8, lines 32 to 34). However, this is not concerned with 3D real world data that has been created from the image data. It can be seen in particular from Figures 3C to 3E and 5B and 5C that the bounding boxes relate purely to allowing analysis of the two dimensional image data.

Accordingly, since neither Kosuge or Bachelder disclose any of features A to E above, it is respectfully submitted that their individual or combined teachings could not lead a skilled person to the invention of Claim 1. It is respectfully submitted therefore that Claim 1 is novel and non-obvious in the light of the teachings of Kosuge and Bachelder.

With regard to Buckley, the Applicant agrees that Buckley discloses an apparatus in which the captured image data components from the camera are used to generate three dimensional data representing the object. However, Buckley employs a system that uses one camera and a laser line scanner, or multiple cameras, to produce its object model using triangulation (see Figure 1, column 5, lines 57 to column 6 line 5; Figure 5; and column 5, lines 65 to column 6,

Applicant : Jan Antonis
Serial No. : 10/822,476
Page : 13

line 5). This is the prior art solution identified in paragraphs [0004] to [0007] of the present Patent application. This is explained in more detail in the passage identified by the Examiner at column 2, lines 42 to 65 of Buckley. Crucially, because Buckley has the capacity to create multiple images (either by scanning or using multiple cameras) it has no need whatsoever for Features B or D of Claim 1 as set out above. Accordingly, Buckley's teaching could not lead a skilled person to the invention of Claim 1 since Buckley essentially provides an alternative solution to the problem being addressed by Claim 1. Therefore, Buckley's teaching, either taken on its own or combined with Kosuge and Bachelder, would lead a skilled person away from the invention.

It is respectfully submitted that the invention of Claim 1 is not obvious in the light of Buckley, or in the light of the combined teachings of Kosuge, Bachelder and/or Buckley.

Regarding Claim 2, this claim defines how the object edge data component is adjusted in situations where an edge profile of the object is perpendicular to the object plane, or is undercut. As such, it relates to how the captured image data, after it has been projected into the object plane, is adjusted to compensate for parallax error. As described above in relation to Claim 1, this adjustment is not equivalent to, and cannot be replicated by, moving the object with respect to the field of view of the camera, since the adjustment must be performed on the data after the image has been captured. The movement of the object described by Kosuge at column 8, lines 62 to 64 occurs prior to an image being captured and so is not relevant to the issue of how to adjust the captured image data in order to compensate for parallax error. Moreover, since, as explained above, neither Kosuge, Bachelder or Buckley are concerned with creating three dimensional object data from a single two dimensional image, the problem of compensating for parallax error does not arise and so none of these documents disclose, or have the need of, the features of Claim 2. It is respectfully submitted therefore that the individual or combined teachings of these documents could not lead a skilled person to the subject matter of Claim 2.

Regarding Claim 3, the same comments apply as are made in relation to Claim 2. With regard in particular to the Examiner's reference to column 4, lines 64 to 66 of Bachelder, as described above, Bachelder is concerned with determining two dimensional shapes from two

Applicant : Jan Antonis
Serial No. : 10/822,476
Page : 14

dimensional image data and not with creating three dimensional object data from two dimensional image data.

Regarding Claim 4, the same comments apply as are made in relation to Claim 3.

Regarding Claim 5, the feature of this claim defines a preferred technique by which the system of the invention determines whether or not an object edge data component relates to an edge of the object that is on the work surface or above the work surface, i.e. a lower or upper edge of the object being inspected.

The Examiner contends that this technique is disclosed by Bachelder. The applicant respectfully disagrees. Firstly, as explained above, the techniques taught by Bachelder are all performed on the two dimensional image data and not on the object data as required by Claim 5. Secondly, Bachelder is not concerned with creating three dimensional object data from the two dimensional captured image data and so is not interested in whether or not an object edge data component relates to a lower or upper edge of the object. Therefore, the feature of Claim 5 would be of no use to Bachelder. Bachelder does make a decision as to whether or not a boundary point of the image data corresponds to a top edge of the object model (see column 8, lines 32 to 46). However, this is achieved by determining whether or not a boundary point of the 2D image data lies within a particular bounding box. This is quite different from the technique proposed in Claim 5 which involves comparing the value of the difference of first and second parameter values against threshold value, and is based on object edge data components rather than image components.

The specific passage of Bachelder (column 9, lines 51 to 63 and 48, 50) identified by the Examiner relates specifically to fitting lines 155A to 155D (Figure 5E) to two dimensional boundary points 150 (Figure 5D) that have been determined as edge points. Boundary points that are outside the bounding boxes as shown in Figures 5B and 5C are discarded. It is emphasised that this is a two dimensional analysis of two dimensional data in order to perform line fitting and so to model the object. This has nothing to do with determining whether or not the edge of the object is a lower edge or an upper edge.

Applicant : Jan Antonis
Serial No. : 10/822,476
Page : 15

Moreover, Bachelder does not disclose any of the following features of Claim 5: calculating a respective first parameter relating to a notional reference line extending from the object edged data component, calculating a second parameter relating to a notional line extending between the object data component and a reference point in the object plane, and comparing the difference between said first parameter and said second parameter against a threshold value.

It is respectfully submitted therefore that the teaching of Bachelder either on its own or in combination with Kosuge does not disclose the features of Claim 5 or could not lead a skilled person to the features of Claim 5.

Regarding Claim 6, the features of this claim are dependent on Claim 5. Since Bachelder does not disclose the features of Claim 5, it is respectfully submitted that it cannot disclose the features of Claim 6 either.

With regard to the passage of Bachelder identified by the Examiner (columns 8, lines 32 to 46 in Figure 3E) in relation to Claim 6, this states clearly that Bachelder decides that a boundary point in the two dimensional image data corresponds to a top edge of the object simply by deciding whether or not it falls into a particular bounding box. This does not involve the notional reference lines, first and second parameters, and threshold values comparisons of Claim 5, or the more specific definition of the first parameter given in Claim 6.

Regarding Claims 7 and 8, the features of these claims relate to preferred implementations of the technique described in Claim 5 and so similar comments apply as are made in relation to Claims 5 and 6.

With regard to Bachelder's steps 42, 44 and 46 identified by the Examiner in connection with Claim 7, Applicant agrees that Bachelder discloses finding points in bounding boxes and comparing the orientation of points with expected orientations thereby categorising points by correlating with a model or a real world object. Applicant cannot see any connection between this methodology and the techniques disclosed in Claims 5, 6 and 7. Bachelder's

Applicant : Jan Antonis
Serial No. : 10/822,476
Page : 16

technique does not involve the calculation and comparison of parameters as is required by Claims 5 to 7. Instead it simply decides whether or not a given point is within a given bounding box. Bachelder then has to make a comparison with a real world model in order to categorise the point. This is not relevant to the subject matter of Claims 5 to 7.

Claim 8 relates to a preferred implementation of the technique of Claim 5 and so similar comments apply as have been made in connection with Claims 5 to 7 and it is respectfully submitted that Bachelder does not disclose the feature of Claim 8. With regard to the Examiner's specific comments concerning column 10, lines 19 to 36 and steps 36, 42, 44 and 46 described by Bachelder, Applicant cannot see any connection between this disclosure and the subject matter of Claim 8.

It may be useful to note that the subject matter of Claims 5 to 8 relate to the illustrations in Figures 3 and 5 of the present application from which it can hopefully be seen that the techniques defined in Claims 5 to 8 do not relate to determining whether or not points are in bounding boxes, or to the comparison of data with models or real world objects.

Regarding Claims 9 and 10, Buckley's technique referred to by the Examiner on page 12 of the examination report and described at column 6, lines 6 to 67 and column 7, lines 1 to 67, column 8, lines 1 to 14 of Buckley are concerned with where the laser light (5) from the laser (3) intersect with the object (8). By scanning the object with the laser, Buckley is able to build up enough data (by taking multiple images) to create a three dimensional data record of the object. Intersection of the laser light with the object (8) has got nothing to do with the intersection of the line of sight of the camera's focal point to the edge of the object, as recited in Claim 9. Moreover, the technique described in Claim 9 or 10 is only necessary when trying to produce three dimensional object data from a single two dimensional image taken by the camera. Since Buckley does not use a single image of the object (instead it uses a series of images capturing the laser lines as they scan across the object), there is no need for Buckley to perform the techniques described in Claim 9 or 10. It is respectfully submitted therefore that Buckley does not disclose the features of Claim 9 or 10.

Applicant : Jan Antonis
Serial No. : 10/822,476
Page : 17

With regard to Claims 11 to 13, these are of corresponding scope to Claim 1 and so similar comments apply.

In light of the above amendments and remarks, Applicant respectfully requests reconsideration of the present application and respectfully solicits a Notice of Allowance of all claims. It is respectfully submitted that the application is in order for allowance.

Should the Examiner have any questions or suggestions, she is invited to contact the undersigned at (616) 975-5506 or at collins@vglb.com.

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